THE RELATIONSHIP OF SECONDARY CAVITY NESTERS TO SNAG DENSITIES IN WESTERN CONIFEROUS FORESTS

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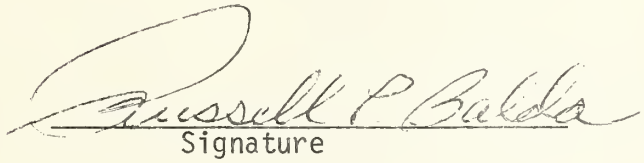
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I. Introduction

As populations increase and added demands are placed on our forests for materials, food, and fiber it becomes imperative that certain guidelines and constraints be developed which allow forest managers to make wise decisions about manipulating our public forests for the benefit and well being of the citizenry. To date, non-game birds have received but scant attention as we manipulate our public forests. This is somewhat ironic as non-game birds play an important role in insect consumption and also provide recreation for a segment of our population which now out numbers hunters.

This report deals with that segment of the bird populations in the ponderosa pine forest that nest in old woodpecker holes, crevices and naturally occurring cavities. These species are referred to herein as secondary cavity nesters. These species have only limited powers of excavation and, therefore, rely heavily on cavities made by woodpeckers, and naturally occurring crevices and cavities usually formed by lightening and heartwood rot. These cavities obviously accumulate through time and are usually most abundant in dead and dying old stumps referred to as snags.

My charge is as follows:

> Based on existing data, specify in a report the minimum number of dead and dying snags per acre that are required to support populations of secondary cavity nesting birds at a level where normal diversity and density of species is maintained. Display to the extent possible by means of graphic tools the effects upon both diversity and density

brought about by a step by step reduction in the number of snags and the cavities they provide.

A valid, realistic and much needed study designed to gain an understanding of the importance and role of secondary cavity nesting species in the community and the relationship and dependence of these birds upon snags must investigate the following points.

Snags

1. Determine and map the number of snags per unit area.

2. Determine the age of each snag; its height, DBH, degree of rottenness, and position in relationship to other live vegetation (shrubs, trees).

3. Determine the number and position (height, direction) of all old holes and natural cavities in the snags.

4. By direct census, determine the utilization of each snag for nesting, recording when and which cavities are being used.

5. By direct census, determine the utilization of each snag for winter roosts.

6. Determine if any other tree species may provide exceptionally large numbers of suitable nesting cavities (i.e. Gambel Oak, Aspen).

7. Determine the length of time a snag will provide usable cavities to the birds.

Secondary Cavity Nesting Birds

1. Determine the absolute and relative densities of all breeding birds to ascertain the absolute density and proportion of the total density that is contributed by secondary cavity nesters.

2. By snag census, determine what proportion of the secondary cavity nesters actually nest in dead and dying snags and what proportion use woodpecker holes and natural cavities in live trees.

3. Determine the winter densities of all birds per area (plot) to determine the absolute density and what proportion of this total is contributed by secondary cavity nesters and roosters.

4. By direct census determine what proportion of the secondary cavity roosters utilize snags for winter roosts.

5. During the breeding season determine the utilized area of each pair of secondary cavity nesters, the number of snags present per utilized area and the amount of overlap of these utilized areas.

6. Determine the foraging pattern of all secondary cavity nesters to show the importance of snags as a foraging substrate.

7. Determine the major food categories of all secondary cavity nesters and, if possible, the proportions of different food items taken when in residence.

8. Take note of all special uses made of particular snags such as hunting perches for raptors and insect hawking birds, nest sites for large raptors, storage locations for Acorn and Lewis' Woodpeckers, and song posts for a variety of birds.

These types of data need be gathered simultaneously from permanent plots over a period of years. Experimental tests of hypotheses generated from the data involving removal of all or a portion of the snags from some plots will also be necessary to strengthen the results and improve their predictive value.

Studies of this nature should be done on a regional basis. Only after such studies have been conducted and the data carefully analyzed will the role of snags as they relate to the avian community be truly understood.

Obviously most of the information listed above has not been gathered or is fragmented in time and space in the literature thereby greatly reducing its use and predictive value for other situations and habitats. In order to obtain a preliminary estimate of the value of snags to secondary cavity nesting birds, it is necessary that this report contain, in addition to appropriate pertainent data at hand, certain assumptions, extrapolations, and "best guesses" in order to come to a figure which will represent the minimum number of snags needed to support realistic or natural densities of secondary cavity nesting birds and maintain the natural diversity of the avian community. Quite obviously the evidence used to support a particular figure will be indirect and the figures should be taken as tentative. Because of the time limitations and the kind of appropriate data on hand this report will concentrate on the ponderosa pine forest of the southwest with limited attention given the mixed coniferous forest.

Numerous works both published and otherwise were consulted for data and interpretations in preparing this report. All data from the Chiricahua Mountains, southeastern Arizona are from Balda (1967). Data from the Beaver Creek Watershed are from Szaro and Balda (unpublished data). Bird densities from the San Francisco Peaks, the Pearson Natural Area, and the White Mountains are those reported in Carothers et al. (1973). V. Scott's excellent reports were invaluable and I urge all concerned with this problem to pay special

attention to his findings. Data on the number of broods per pair were obtained from several sources including, Bent (1963,1964) Brandt (1951), Kilham (1968), Marshall (1939, 1957), Davis,Fisher, Davis (1963) and personal observations.

For the sake of brevity, only common names of the species are listed throughout. Scientific names for all species referred to herein may be found in the A.O.U. Checklist (1957, 1973) and Kearney and Peebles (1969).

II. Secondary Cavity Nesting Bird Densities in Natural Ponderosa Pine Forests.

First, it is necessary to determine the number of secondary cavity nesting species and their densities so that their relative importance or dominance in the community can be ascertained. Breeding bird densities have been determined in three "undisturbed" ponderosa pine forests in Arizona over the past nine years by personnel at Northern Arizona University using the spot-map method (Kendeigh 1944) (Table 1). These data indicate that secondary cavity nesters number between six and nine breeding species in the ponderosa pine forests of Arizona on plots of about 30 acres. These species make up between 26 and 30 per cent of all the breeding species present. These percentages would be somewhat higher if a) owls would have been censused on the Pearson Natural Area and Watershed 13, Beaver Creek b) American Kestrels had been present on the plots. In some years in some places, American Kestrels are common but such was not the case in the studies reported herein, nor were nocturnal owls censused in the first two mentioned plots. Based on these data, it is believed that secondary cavity nesters make up about one-third of the total breeding species in the ponderosa pine forest.

TABLE 1

Densities of Secondary Cavity Nesters of Three Natural Ponderosa Pine Forests in Arizona (pairs/100 acre)

Species	Location		
	Pearson Natural Area, Flagstaff (a)	Watershed 13 Beaver Creek (b)	Chiricahua Mts. SE Arizona (c)
Pygmy Nuthatch	26	15	43
Violet-green Swallow	30	9	3
Mountain Chickadee	20	8	0
Mexican Chickadee	0	0	7
Western Bluebird	15	6	20
White-breasted Nuthatch	7	11	10
Flammulated Owl	0	0	7
House Wren	0	0	10
Pygmy Owl	0	0	1
Western Flycatcher	7	7	7
Total Species	6	6	9
Per Cent of all Breeding Species	26	30	29
Total Breeding Pairs Per 100 acres	105	56	108
Per Cent of all Breeding Pairs	45	42	32
H'	2.3938	2.5153	2.5913

a) Data from Carothers et al. 1973.
b) Data from Szaro and Balda (unpublished)
c) Data from Balda (1967).

In addition to the ten species listed in Table 1, other secondary cavity nesters in the ponderosa pine forest include the Spotted Owl, Saw-whet Owl, American Kestrel, Brown Creeper, Purple Martin, and Mountain Bluebird. These 16 species can be categorized by general food habitats as shown in Table 2. Eighty-one per cent of all secondary cavity nesters are insectivorous and three are primarily carnivorous but two of these (Pygmy Owl, Saw-whet Owl) do take some insects.

Secondary cavity nesters contribute between 56 and 108 breeding pairs per 100 acres of ponderosa pine forest. This is between 32 per cent and 45 per cent of all breeding pairs (Table 1). These numbers would be slightly higher if conditions a) and b) mentioned above occurred. Secondary cavity nesters contribute between 40 and 55 per cent of all breeding pairs in the ponderosa pine forest. This is a most substantial percentage and indicates the realistic value of these species as a group.

If each breeding species was equally limited in density by a combination of factors, such as space, food, nest sites, song posts, predators, etc. then one could expect that the proportion of cavity nesting species in the pine forest would accurately reflect the proportion of breeding pairs. Then, if secondary cavity nesting species make up one-third of the avian community, they should contribute one-third of the breeding pairs. This prediction is low as secondary cavity nesters contribute close to 50 per cent of all breeding pairs. These figures suggest that secondary cavity nesters as a group are somewhat more successful than the "average" ponderosa pine forest bird in undisturbed habitats.

TABLE 2

Food Habits by General Categories for the Sixteen

Secondary Cavity Nesters of the Southwestern Ponderosa Pine Forest

Species	Category
	I. Gleans insects from foliage & bark
Mexican Chickadee PR*	
Mountain Chickadee PR	
White-breasted Nuthatch PR	
Pygmy Nuthatch PR	
House Wren SR**	
Brown Creeper PR	Total Number of gleaners = 6
	II. Hawks Aerial Insects from Perches
American Kestrel SR	
Flammulated Owl SR	
Western Flycatcher SR	
Violet-green Swallow SR	
Purple Martin SR	
Mountain Bluebird PR	
Western Bluebird PR	Total Number of hawkers = 7
	III. Feeds on Small Mammals and Birds
Pygmy Owl PR	
Saw-whet Owl PR	
Spotted Owl PR	Total Number of raptors = 3

*Permanent Resident
**Summer Resident

This success may in part be due to the ability of some of these species to overwinter in the ponderosa pine forest. Of the 16 secondary cavity nesters, ten or 63 per cent of the species are permanent residents and six are summer residents. The ten species, Saw-whet Owl, Pygmy Owl, Spotted Owl, Pygmy Nuthatch, Brown Creeper, White-breasted Nuthatch, Mountain Chickadee, Mexican Chickadee, Western Bluebird, (and occasionally the American Kestrel) do not occur in all areas in all years but Table 3 lists the proportion of total species and of total individuals contributed by secondary cavity nesters in specific ponderosa pine forests in winter. Although only four or five secondary cavity nesters overwinter in an geographic area, in the ponderosa pine forest, they contribute between 22 and 42 per cent of all species. In terms of overall density, however, the secondary cavity nesters contribute between 63 and 73 per cent of all winter residents. This success is undoubtably related to the use of old woodpecker holes and cavities as roosts during the cold winter nights. Of special interest is the fact that all five species listed in Table 3 are insectivorous. Thus, the major consumption of forest insects, larvae, and eggs in the winter months is done by the secondary cavity nesters. All insects removed in winter are obviously prevented from reproducing in the subsequent spring. This means that secondary cavity nesters may play an extremely important role in insect control by their feeding activities in the winter months, the very time when insect populations are low.

TABLE 3

Relative Densities of Wintering Secondary Cavity Nesting Birds in the Ponderosa Pine Forest (Pearson Natural Area)

Species	Year (birds/hr.) 1966-1967	1972-1973
Pygmy Nuthatch	10.3	1.09
White-breasted Nuthatch	4.1	0.64
Mountain Chickadee	3.4	1.00
Western Bluebird	3.4	0.27
Mountain Bluebird	0	0.18
Total Species	4	5
Per Cent of All Wintering Species	22	42
Total Bird Hours	21.2	3.18
Per Cent of All Winter Bird Hours	73	63

III. Densities of Secondary Cavity Nesting Species on Beaver Creek Watersheds Subjected to Various Treatments.

A study presently underway on the Beaver Creek Watershed, near Flagstaff, Arizona, provides some limited data about the effects of various snag removal policies on secondary cavity nesting species. The data are confounded, however, by the fact that in areas where snags were removed, the live tree density was also reduced. It is difficult, therefore, except in a few cases to say with certainty what affect each of these factors has on the bird populations. Table 4 lists species and their densities for four study areas. In areas I and II foliage density was reduced when compared to that of two plots (III) used as control areas. In area I, all snags (pine and oak) were removed whereas in area II only pine snags were removed. In two areas (III) no cutting has taken place. Secondary cavity nesting species show a dramatic increase, from three species to seven species as the density of snags increases (Table 4). This better than 100 per cent increase, however, cannot be totally accounted for by the increase in snags. Two of the species absent from area I appear to require shaded areas and some thick underbrush. The absence of the Western Flycatcher and House Wren, therefore, cannot totally be accounted for by the lack of nest sites in snags. The total absence of Violet-green Swallows and Mountain Chickadee is believed directly related to the absence of snags. Noting that owls were not censused on these plots means that about one-fifth to one-sixth of the snag nesting species will be removed from the avian community should all snags be removed.

This amounts to about one-tenth of the total breeding bird species in the community. In an area devoid of all snags, secondary cavity nesters account for 18.8 per cent of all species whereas in a mature area they account for 35 per cent of all species, an increase of 16 per cent without data for owls. Not only is breeding bird species diversity affected by snag removal but the densities of secondary cavity nesters is also affected. As the density of snags increased over the four plots the densities of cavity nesters increased from 19 to 55 pairs per 100 acres. The latter figure is for an area not cut for the past 60 years, and quite possibly reflects a mature coniferous forest. Thus, almost a three-fold increase in densities is seen from a snag-barren area to a mature, undisturbed ponderosa pine forest. The Shannon formula (H') indicates that species diversity of secondary cavity nesters is reduced by 50 per cent when all snags and oaks are removed from the pine forest. The three species which demonstrate the greatest decrease in densities are the Violet-green Swallow, Pygmy Nuthatch and Mountain Chickadee. The latter two are common permanent resident insectivores and, therefore, quite possibly important members of the avian community.

As the number of snags increased the proportion of secondary cavity nesting pairs within the avian community increased from 21 per cent to 38 per cent. Their importance, in terms of predominance almost doubles and undoubtably reflects the presence of suitable nesting and roosting sites.

TABLE 4

Densities of Secondary Cavity Nesting Birds on Beaver Creek Watersheds Subjected to Various Snag Removal Treatments (pairs/100 acres)

Species	All Snags and Oaks Removed I	Oaks Present II	Oak and Pine Snags Present III
Violet-green Swallow	0	3	9*
White-breasted Nuthatch	9	9	10
Pygmy Nuthatch	2	3	15
Western Bluebird	8	12	7
Mountain Chickadee	0	9	7
Western Flycatcher	0	5	6
House Wren	0	2	1
Total Species	3	7	7
Total Breeding Pairs	19	43	55
Per Cent of all Breeding Species	18.75	33.33	35
Per Cent of all Breeding Pairs	21	26	38
H'	1.38	2.56	2.60

*Average densities for two plots

The above presentation indicates the two ends of the snag density spectrum (no snags to all snags present) without knowledge of the actual number of snags present on any of the study areas. It is necessary, therefore, to approach the question from a different point-of-view, which is more speculative and less exacting. In Table 4, the density differences between plots will crudely indicate what proportion of the population nests in snags by using area I as a standard. For example, Violet-green Swallows absent from area I, appear to place 100 per cent of their nests in snags. All percentages calculated in this fashion are given in Table 5. Values range from 33 per cent to 100 per cent for the seven species listed in Table 4 with an overall average of 76 per cent. This figure should be reasonably close for the entire group of secondary cavity nesters listed in Table 5.

A more subjective calculation is to simply tally all located nests across geographic areas to get a gross overall percentage for snag usage. Table 6 lists figures from the Chiricahua Mountains, Beaver Creek Watersheds, Apache National Forest, and the authors personal observations in the Flagstaff area. For a total of 141 secondary cavity nests made by 13 of the 16 species of secondary cavity nesters in the ponderosa pine forest the percentage varied from a low 67 per cent to a high of 92 per cent of all located nests being placed in dead and dying snags. The grand average for these 141 nests was 87 per cent placed in dead and dying snags.

Based on the two derived and extrapolated figures (76 per cent and 87 per cent) it can be concluded that on an average about 82 per cent of all

TABLE 5

Proportion of Nests Secondary Cavity Nesters Place in Dead Snags

Species	Proportion of Nests (%) (from Table 4)
Violet-green Swallow	100
White-breasted Nuthatch	10
Pygmy Nuthatch	87
Western Bluebird	33
Mountain Chickadee	100
Western Flycatcher	100
House Wren	100

Overall average per cent = 76

secondary cavity nests are in dead and dying snags, when secondary cavity nesting species are viewed as a group. Obviously this figure is a tentative one, and does not account accurately for individual species. For example, of the 141 nests listed in Table 6, 34 were constructed by the Violet-green Swallow and of these, 97 per cent were in dead and dying snags. Thirty-seven of the 141 nests were owned by Pygmy Nuthatches and 89 per cent were in dead and dying snags. These figures are very close to those listed in Table 5. Because these two species are, in many cases, among the most common cavity nesting species in ponderosa pine forests (Table 1) it is this authors opinion that the above figure accurately represents what these two species use. A reasonable figure for proportion of nests placed in snags would be 82 per cent for all other secondary cavity nesters. This figure will be used in important calculations to be presented later.

IV. Areas Utilized by Pairs of Secondary Nesting Species.

The information presented above relates densities of secondary cavity nesting species to plot size or to a conventional standard, 100 acres. These figures, however, do not take into account the actual areas of the plots utilized by the breeding pairs. Using the spot-map method, it is possible to measure a minimum utilized area by plotting on a map of the area all positions where birds of each pair were sighted. By enclosing all locations of a given pair on a grid map and then tracing these areas with a planimeter one can determine the minimum utilized area for each pair. Data for territorial species can then be tabulated to determine what per cent

TABLE 6

Percentage of Nests Secondary Cavity Nesters Placed in Dead Snags in the Ponderosa Pine Forest

Status of Tree	Chiricahua Mts.	Beaver Creek Watershed	Scott's Data Apache Nat'l For.	Pers. Obs. Flagstaff, AZ	Total
Dead and Dying Snags	16 (67)*	27 (100)	44(92)	36 (86)	123 (87)
Live Trees	8 (34)	0 (0)	4 (8)	6 (14)	18 (13)
Totals	24	27	48	42	141
Number of Species	7	5	10	9	13

* Per Cent of Total

of a given plot is utilized by secondary cavity nesting species. Table 7 lists the utilized areas for five species of secondary cavity nesting species in a ponderosa pine forest in the Chiricahua Mountains, Arizona. The weighted grand mean of all measured territories is 1.21 acres. In an uncut area (13) of the Beaver Creek Watershed mean territory sizes for five species ranged from 1.37 acres for the White-breasted Nuthatch to 2.85 acres for the Mountain Chickadee (Table 8). The weighted grand means for the area is 1.82 acres. The average utilized area for undisturbed ponderosa pine forest, for the six species shown in Table 7 and 8, is 1.4 acres per breeding pair. This figure accounts for neither the carnivorous owls nor the American Kestrel which have large territories nor the Violet-green Swallow which is not territorial. For other species, data is lacking for such a calculation. It is felt that this figure is a crude but a usable one until more accurate data are available. The major limitation of these figures is the few species it covers.

Another means of determining the actual amount of areal space the cavity nesting species use is to determine what per cent of each plot they used. For an uncut watershed in the Beaver Creek Watershed, the actual per cent of total utilization was 80 per cent for the five species listed in Table 8. Again, these figures did not account for the other nine secondary cavity nesting species because no data are available. One could argue that these figures are inflated because some, if not all, of the five species have overlapping territories. The amount of overlap in the area discussed above was 12.6 per cent of the area utilized by the five species (Fig. 1).

TABLE 7

Utilized Areas of Five Species of Secondary Cavity Nesting Species in the Ponderosa Pine Forest, Chiricahua Mountains, Arizona (in acres)

Species	Number Measured	Mean	S.D.	Max.	Min.
White-breasted Nuthatch	4	2.21±0.52		2.64	1.55
Mexican Chickadee	2	1.98±0.15		2.08	1.87
House Wren	4	1.10±0.52		1.86	0.66
Western Bluebird	8	1.06±0.36		1.50	0.71
Pygmy Nuthatch	14	.94±0.17		1.25	0.54

Weighted Grand Mean = 1.21 acres

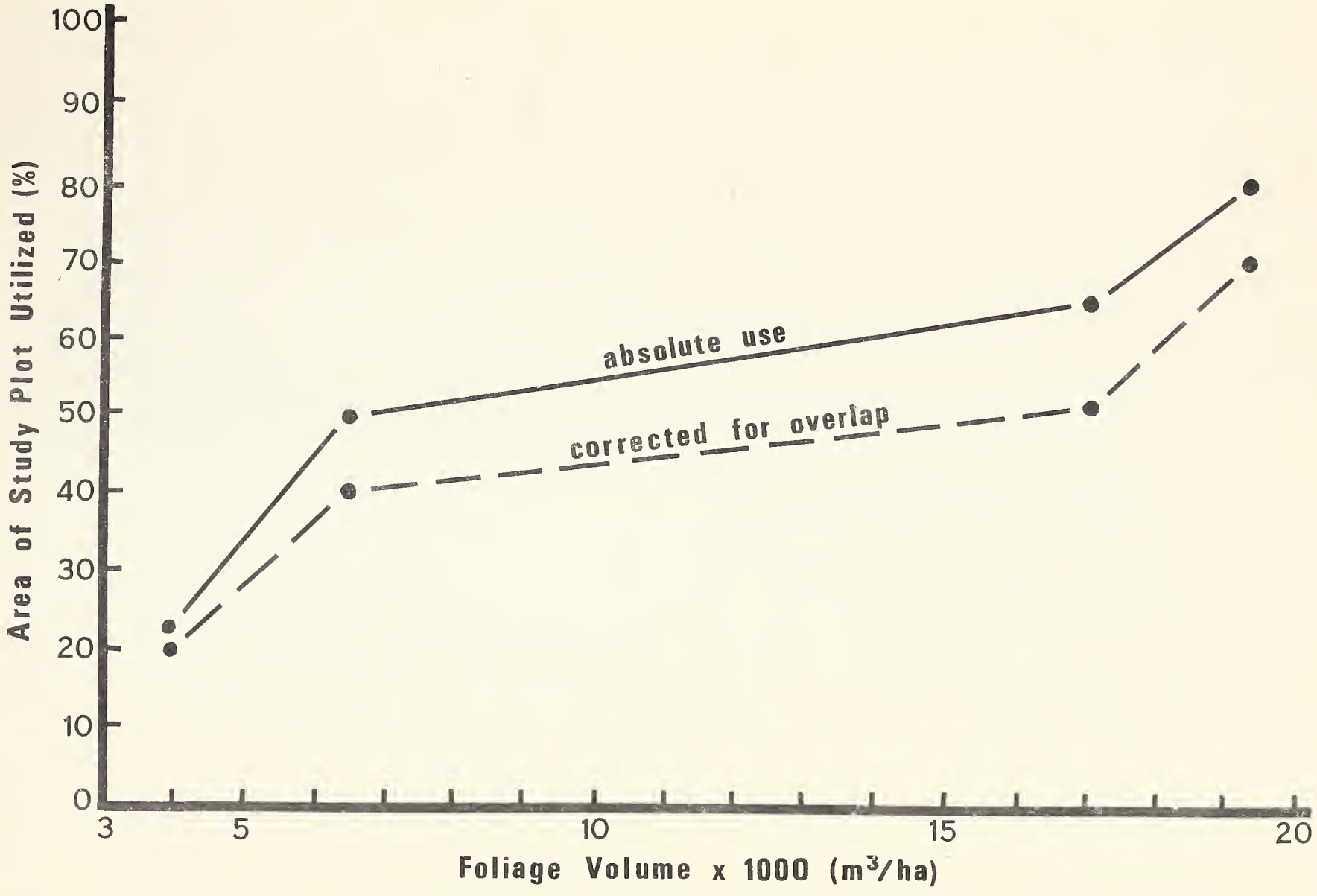
TABLE 8

Utilized Areas For Five Species of Secondary Cavity Nesting Birds on Watershed 13 (in acres)

Species	Number Measured	Mean	S.D.	Max.	Min.
White-breasted Nuthatch	4	1.37 ± 0.78		1.80	0.86
Pygmy Nuthatch	5	2.08 ± 0.20		2.39	1.87
Western Bluebird	2	1.42 ± 0.72		1.93	0.92
Mountain Chickadee	2	2.85 ± 1.06		3.60	2.10
Western Flycatcher	2	1.41 ± 0.04		1.44	1.39

Weighted Grand Mean = 1.82 acres

Figure 1. Amount of area, in per cent, of 100 acres used by five species of secondary cavity nesting species on four plots on the Beaver Creek Watershed.


100
90
80
70
60
50
40
30
20
10
0
Area of Study Plot Utilized (%)
absolute use
corrected for overlap
3
5
10
15
20
Foliage Volume x 1000 (m³/ha)

This relatively small amount of overlap is most certainly offset, and then some, by the areas utilized by the nine species not accounted for in the above analysis, and the fact that all measurements were of minimum areas of use. One must conclude that with available data, this type of analysis is highly inaccurate and there is no doubt that an 80 per cent utilization figure is low. I believe a figure of very near 100 per cent is accurate and will be used in this report for the calculations to follow.

V. Use of Snags for Foraging by Five Species on the Beaver Creek Watershed.

Snags not only provide nest and roost sites for secondary cavity nesting species but also harbor insects that some of these species consume, and act as hawking perches for other insectivorous species. In determining the foraging patterns of ponderosa pine forest birds, we recorded all foraging substrates used by these birds as events and also timed how long the birds foraged on each substrate, or used it as a perch to hawk from. In an undisturbed watershed plot (13) secondary cavity nesting species varied in their use of snags from 6.3 per cent of all observations by the Mountain Chickadee to 25 per cent of all observations by the White-breasted Nuthatch. The Mountain Chickadee spent 7.9 per cent of its time on snags whereas the Western Bluebird spent 20.9 per cent of its time on them. Overall, the five species spent about ten per cent of their time on snags (Table 9). This figure does not account for how much food these birds obtained in this time and this author believes the birds obtain more than ten per cent of their food either directly

TABLE 9

Snag Use on Watershed 13 by Secondary Cavity Nesting Birds

Species	Number of Observations	Time in Seconds	Observations in Snag	Time in Snag	Percent Observations in Snags	Percent of Time in Snags
White-breasted Nuthatch	48	1132	12	104	25.00	9.19
Pygmy Nuthatch	156	699	13	43	8.33	6.15
Western Bluebird	30	632	3	132	10.00	20.89
Mountain Chickadee	96	1580	6	124	6.25	7.85
Western Flycatcher	24	601	3	50	12.50	8.32
Total	354	4644	37	453	10.45	9.76

or indirectly from snags but no data are available. Although a figure of ten per cent may appear low, in reality it most likely indicates that snags are used far more often than their availability in the ponderosa pine forest suggests. Certainly snags do not provide ten per cent of the foraging substrate or biomass available to the birds in ponderosa pine forests. The actual per cent of foraging substrate provided by snags is probably less than one per cent of the total. The ten per cent use figure indicates snags are heavily used for foraging purposes and contribute substantially to the food base of the secondary cavity nesting species. The use of snags by all other nesting species has not yet been analyzed but my impression is that secondary cavity nesting species are not unique in their heavy use of snags for foraging.

VI. Calculations to Determine the Density of Snags Necessary to Maintain Natural Species Diversity and Densities in the Ponderosa Pine Forests.

Based on the data presented above, it is possible to calculate an approximate figure for the number of snags that must be left in the forest to maintain the cavity nesting species at natural densities. This calculation, by necessity, must take the density figures presented earlier into consideration and these figures vary because of a constellation of limiting factors. I believe enough snags must be left in the forest to accommodate each species when other limiting factors are not severe. Population levels may fluctuate greatly and it would be a serious mistake to provide enough nesting snags to maintain densities only at low population levels. Therefore, I

have calculated two figures, one for average densities for each species listed in Table 1, and one for the maximum densities for each species shown in that table (Tables 10, 11). For the five species not found in Table 1, I assumed densities of one pair per 100 acres in both calculations. For per cent of snag use shown in Table 10 and 11, I used the figures from Section III and Tables 4 and 5. When no accurate figures were available, I used 82 per cent as the percentage of all nests placed in snags. The number of snags needed per year was calculated by determining the number of nesting cycles each species goes through per summer. Some species will nest only once per summer whereas others will normally nest twice. Nesting success is never 100 per cent, therefore, one must account for renesting attempts. Because little useful data is available on this point, I have estimated that 66 per cent of all nests will be successful and 34 per cent will fail. If a species raises one brood per year then it needs, on the average, 1.33 snags per pair and a species that nests twice needs 2.66 snags per pair. From personal observations I conclude that renesting attempts are not attempted in the same hole or snag. Using the above mentioned data and assumptions, I conclude that a minimum number of snags necessary to maintain natural species diversity and densities at average levels is 173 snags per 100 acres (Table 10). Because of widely fluctuating densities, however, I believe this is a very low figure and I would not recommend its use. By using the maximum density figures, the calculations result in a figure of 268 snags per 100 acres. It is my opinion that the best situation is to maintain the latter number of snags per 100 acres. If demands on the forest are extreme, and constraints

TABLE 10

Snag Density Necessary Per 100 Acres to Maintain Natural Species Diversity and Average Densities

Species	Average Density	Per Cent Snag Use	Snags/Yr	Snags/Species/ 100 Acres
Pygmy Nuthatch	28	89	2.66	66.4
Violet-green Swallow	14	97	1.33	18.1
Mexican or Mountain Chickadee	12	82	1.33	13.1
Western Bluebird	14	82	2.66	30.5
White-breasted Nuthatch	9	82	1.33	9.8
Flammulated Owl	7	82	1.33	7.6
House Wren	3	82	2.66	6.5
Pygmy Owl	1	82	1.33	1.1
Western Flycatcher	7	82	2.66	15.3
Saw-whet Owl	1	82	1.33	1.1
American Kestrel	1	82	1.33	1.1
Purple Martin	1	82	1.33	1.1
Mountain Bluebird	1	82	1.33	1.1
Total Average Density	99		Total Snags/ 100 Acres	172.8

TABLE 11

Snag Densities Necessary Per 100 Acres to Maintain Natural Species Diversity and Maximum Densities

Species	Maximum Density	Per Cent Snag Use	Snags/Yr	Snags/Species/ 100 Acres
Pygmy Nuthatch	43	89	2.66	101.9
Violet-green Swallow	30	97	1.33	38.7
Mexican or Mountain Chickadee	20	82	1.33	21.8
Western Bluebird	20	82	2.66	43.6
White-breasted Nuthatch	11	82	1.33	11.9
Flammulated Owl	7	82	1.33	7.6
House Wren	10	82	2.66	21.8
Pygmy Owl	1	82	1.33	1.1
Western Flycatcher	7	82	2.66	15.3
Saw-whet Owl	1	82	1.33	1.1
American Kestrel	1	82	1.33	1.1
Purple Martin	1	82	1.33	1.1
Mountain Bluebird	1	82	1.33	1.1
Total Average Density	153		Total Snags/ 100 Acres	268.1

to manage secondary cavity nesters must be minimized, I believe a tolerable figure would be the average of figures for maximum and average densities which is 221 snags per 100 acres. Only under the most drastic and serious of conditions should the snag density be lowered to 173 per 100 acres.

Another important question that needs to be addressed is how should these snags be distributed over the 100 acres. In Section IV, I calculated that at a very minimum, 80 per cent of the uncut ponderosa pine forests are utilized by secondary cavity nesting species. Based on this low figure, I strongly recommend that an attempt be made to maintain a regular distribution of snags throughout the forest. This means that on every ten acres of ponderosa pine forest, 27 snags should be left.

Tables 10 and 11 point out the approximate proportion of the snags that will be used by each of the secondary cavity nesting species. It is important to note in this regard that permanent resident insectivorous species will, on the average, utilize 69 per cent of all snags at average densities and 67 per cent of all snags at maximum densities. These are the species that probably are most important in insect control and need to be actively protected.

I am in no position to accurately define what constitutes a snag except to suggest that it be a dead or dying tree with a D.B.H. of ten or more inches. I direct the reader to V. Scott's excellent data on this point.

As the number of snags per unit area is reduced, some species will be hindered more than others because some species range widely and consequently

TABLE 12

Snags Necessary Per Utilized Area for Each Secondary Cavity Nesting Species

Species	Average Territory Size	Per Cent Snag Use	Snags/Yr	Snags/Acre of Utilized Area
Pygmy Nuthatch	1.24	89	2.66	1.91
Violet-green Swallow	7.14	97	1.33	0.18
Mexican or Mountain Chickadee	2.42	82	1.33	0.45
Western Bluebird	1.19	82	2.66	1.83
White-breasted Nuthatch	1.79	82	1.33	0.61
Flammulated Owl	1.40	82	1.33	0.78
House Wren	1.10	82	2.66	1.98
Pygmy Owl	100.00	82	1.33	0.01
Western Flycatcher	1.41	82	2.66	1.55
Saw-whet Owl	100.00	82	1.33	0.01
American Kestrel	50.00	82	1.33	0.02
Purple Martin	7.14	82	1.33	0.15
Mountain Bluebird	1.40	82	1.33	0.78

TABLE 13

Relative Order of Sensitivity of Secondary Cavity Nesting Species to Snag Removal

Species	Category
	I. Least Sensitive
Saw-whet Owl	
Pygmy Owl	
American Kestrel	
	II. Moderately Sensitive
Purple Martin	
Violet-green Swallow	
	III. More Sensitive
Mexican Chickadee	
Mountain Chickadee	
White-breasted Nuthatch	
Flammulated Owl	
Mountain Bluebird	
	IV. Most Sensitive
Western Flycatcher	
Western Bluebird	
Pygmy Nuthatch	
House Wren	

have an opportunity to locate new cavities. Other species are territorial and may attempt to raise more than one brood per year. These species will be more sensitive to snag removal. Table 12 calculates the number of snags needed per acre of utilized area for each species. The birds are ranked in Table 13 from those requiring the fewest snags to those requiring the most snags per unit area. In categories III and IV are a total of nine species, all insectivorous, and of which five are permanent residents. This again suggests that wide-spread snag removal will directly affect these most valuable species in the forest.

VII. Mixed Coniferous Forest Secondary Cavity Nesting Birds.

Data are not as readily available on mixed coniferous forest species as they are for ponderosa pine forest birds. Table 14 gives diversity and densities of secondary cavity nesting species from three mixed coniferous forests in Arizona obtained by the spot-map technique (Kendeigh 1944). These data indicate that secondary cavity nesters number between four and eight breeding species. These species make up between 25 and 30 per cent of all breeding species. Most certainly the Saw-whet Owl and Pygmy Owl also nest in this habitat type. Thus, the number and per cent of breeding species is similar to that found in the ponderosa pine forest. Breeding pairs per 100 acres range from 30 to 178, and contribute between 17 and 47 per cent of all breeding pairs per 100 acres. These figures are also similar to those presented for the ponderosa pine forest.

TABLE 14

Densities of the Secondary Cavity Nesting Species of the Mixed Coniferous Forests of Arizona (pairs/100 acres)

Species	Location		
	Chiricahua Mountains (a)	White Mountains (b)	San Francisco Peaks (b)
Brown Creeper	40	5	9
Pygmy Nuthatch	33	0	4
Western Flycatcher	30	5	17
Mexican Chickadee	26	0	0
Mountain Chickadee	0	13	26
Red-breasted Nuthatch	23	7	0
House Wren	18	0	3
Flammulated Owl	4	0	0
White-breasted Nuthatch	4	0	2
Violet-green Swallow	0	0	10
Total Species	8	4	7
Per Cent of All Species	31	25	26
Total Breeding Pairs	178	30	71
Per Cent of All Breeding Pairs	47	17	28

a) Data from Balda (1967).
b) Data from Carothers et al. (1973).

Of the 12 species of secondary cavity nesters inhabiting the mixed coniferous forest, eight or 67 per cent are permanent residents. Of these eight, six are insectivorous and two carnivorous but also eat insects.

Based on the above data, we tentatively conclude that the secondary cavity nesters of the mixed coniferous forest are very important members of the community and require about the same number of snags as do those of the ponderosa pine forest.

VIII. Cautions and Other Considerations.

1. This report deals solely with the secondary cavity nesting species of the Southwestern coniferous forest. It does not incorporate data about other species that use snags for hunting perches or cache sites. The Goshawk, a relatively rare raptor, uses snags for nest-sites and hunting perches. The Acorn and Lewis' Woodpeckers both cache acorns and other foods in dead snags. A recent survey (pers. obser.) reveals that Lewis' Woodpeckers used dead snags exclusively for caching whereas Acorn Woodpeckers use dead and dying snags for about 80 per cent of their caching.
2. Because snags are transient and eventually disintegrate and fall, they are of value to secondary cavity nesting species for only a limited number of years. Thus, it is necessary to leave trees in the pine forest that will become suitable snags

in the future. Severe timber cutting at this time can be detrimental to the cavity nesters in the future.

3. This report does not allow extra snags for winter roosts because we believe ample snags will be available after the summer residents depart in the fall. In this regard, our snag density figures could be conservative.
4. The Starling, an introduced species, is now rapidly invading the ponderosa pine forest of central Arizona. Winter records from Flagstaff have shown a yearly winter increase of from 13 to 65 per cent in some years. In the past 11 years the Starling has changed in status from a rare winter visitor to a common winter visitor. Nests have been found in snags in the vacinity of Flagstaff. Our secondary cavity nesting species cannot compete behaviorally for cavities with Starlings. If present trends continue, secondary cavity nesters will not be able to maintain stable populations if any snags are removed.
5. One might argue that secondary cavity nesting species can use the same holes numerous times for nesting. This usually does not happen, as nestlings tend to foul the cavity and attract parasites. Also, constant use of the same hole may attract predators. Thus, holes apparently must remain unoccupied for sometime between nestings.
6. In the mixed coniferous forest some species of cavity nesters seem especially attracted to Aspen. In this soft wood some excavating

can be done by nuthatches. The role of Aspen to secondary cavity nesters needs special consideration. The same is true for Gambel Oak.

7. Some primary cavity nesting species (those that excavate their own nesting holes) are particular to dead snags. For example, of eight Red-shafter Flicker nests found near Flagstaff, seven were located in dead snags. In the Chiricahua Mountains, 57 per cent of the Red-shafter Flicker nests were in snags and 100 per cent of the Acorn Woodpeckers nests were also in snags. Snags are valuable to these species, and removal below suggested densities may also effect these two insectivorous species.

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